PHASE II: DEMONSTRATION AND VALIDATION

Step 9.0 Update HF/S Design Concepts

Objective:

The objective of this process step is to develop HF/S design concepts

Inputs:

Inputs to this step include the design objectives from the HF/S Plan, outputs of the front-end analysis, and inputs from the System Engineering Program.

Output:

The outputs of this step include alternative concepts as well as inputs to NDI/COTS selection.

Activities associated with each substep are described below:

9.1 Develop System Level Design Concepts

9.1.1 Select systems for HF/S application

9.1.2 Brief system design organization management on objectives, approach, resource and information requirements

9.1.3 Review of system design activity - status and planning

9.1.4 Review of system development documentation

9.1.5 Identify baseline comparison systems (BCS) and identify high drivers and lessons learned from existing systems

- Identify the Initial manning Estimate
- Assemble task sequences in the BCS
- Identify the roles of the human vs automation in the BCS
- Identify the roles of the human vs automation in the emerging system
- Define the network of tasks in the emerging system
- Establish manning estimates by subsystem and condition of readiness
- Compile manning estimates into the Initial manning Estimate

9.1.6 Identify missions and system top-level functions and determine the proposed role of the human vs automation in:

- system configuration, setup and initiation
- system checkout and calibration
- system normal operation
- system contingency operation
- system performance monitoring
- system control
- corrective maintenance
- planned maintenance
- modification of system configuration
- system termination

9.1.7 Analyze and decompose functions and identify requirements associated with performance of functions

9.1.8 Collaborate with operational and engineering personnel to identify the potential for reengineering the allocation of functions, and consolidation, elimination, and simplification of functions

9.1.9 Describe alternate function allocation/role of human strategies

9.1.10 Describe alternate design concepts based on alternate strategies

- Determine the impact of cross training on workload/skill reduction
- Determine the impact of automation of manual operations on workload/skill reduction
- Determine the impact of improved design on workload/skill reduction
- Determine the impact of changes in policy and doctrine on workload/skill reduction
- Determine the potential for improved design to reduce workload and manning.
    - determine the potential for display design
        - determine requirements for displays which are meaningful, readable, integrated, accurate, current, complete, clear, directive, transparent, readily associated with control actions and other related displays, and responsive to information requirements;
        - identify problems with display design in the BCS
        - identify display design improvements
        - identify how display improvements will modify task sequences and/or reduce the likelihood of human error
    - determine the potential for control design
        - determine requirements for controls which are reachable, identifiable, operable, consistent, compatible with expectations and conventions, and simple to use;
        - identify problems with control design in the BCS
        - identify control design improvements
        - identify how control improvements will modify task sequences and/or reduce the likelihood of human error
    - determine the potential for console and panel design
        - determine requirements for consoles and panels including required control and display functions arranged in terms of functions, sequence of operations, and priorities;

        - identify problems with console and panel design in the BCS
        - identify console and panel design improvements
        - identify how console and panel design improvements will modify task sequences and/or reduce the likelihood of human error
    - determine the potential for procedures design
        - determine requirements for procedures which are logical, consistent, straightforward, and which provide feedback;
        - identify problems with procedures design in the BCS
        - identify procedures design improvements
        - identify how procedures improvements will modify task sequences and/or reduce the likelihood of human error
    - determine the potential for communications design
        - determine requirements for communications which are standardized, consistent, intelligible, clear, concise, identifiable, prioritized, and available;
        - identify problems with communications design in the BCS
        - identify communications design improvements
        - identify how communications improvements will modify task sequences and/or reduce the likelihood of human error
    - determine the potential for environmental design
        - determine requirements for environments which are within performance, comfort and safety limits, designed in terms of task requirements, and consider long term as well as short term exposure.
        - identify problems with environmental design in the BCS
        - identify environmental design improvements
        - identify how environmental design improvements will modify task sequences and/or reduce the likelihood of human error
- Determine the potential for task simplification to reduce workload/manning.
    - identify the potential for reducing physical task demands
    - identify the potential for reducing cognitive task demands
    - identify the potential for reducing perceptual-motor task demands
    - develop task simplification concepts
        - reduce the amount of information to be processed,
        - reduce the complexity of the information processing,
        - reduce the number of decisions and options to be handled,
        - reduce the complexity of actions,
        - reduce the needs for interactions with other operators,
        - reduce the extent and complexity of communications,
        - reduce the task performance accuracies required,
        - reduce the special skills and knowledge required,
        - reduce the levels of skills such as reading comprehension,
        - reduce the level of stress associated with the performance of tasks under representative mission conditions,
        - reduce the time constraints.
    - identify how task simplification will modify task sequences and/or reduce the likelihood of human error
- Determine the potential for automation to reduced workload
    - determine for which tasks is increased automation feasible
    - identify the role of the human for tasks for which the level of automation has been

increased
- identify how automation will modify task sequences and/or reduce the likelihood of human error
- determine the potential for cross training to reduced workload
- determine for which tasks is cross training feasible
- identify the role of the human for tasks for which cross training has been implemented
- identify how cross training will modify task sequences and/or reduce the likelihood of human error

9.1.11 Develop task networks associated with alternate concepts

9.1.12 Analyze tasks to identify performance requirements

9.1.13 Conduct workload assessment simulations for each feasible concept

9.1.14 Conduct tradeoffs to select a design concept

9.1.15 Identify human-machine interface (HMI) design requirements

- In designing systems for human performance, the focus from an HF/S perspective is on design of human-machine interfaces (HMI). The classes of HMI are functional , informational, environmental, operational, organizational, cooperational, cognitive, and physical interfaces.

- <u>Functional interfaces</u>
  - *Components* Elements of functional interfaces include:
    - the roles of humans versus automation in system operation, control, maintenance and management;
    - human functions and tasks;
    - roles of system personnel in automated processes (e.g., monitoring, management, supervision, intervention, etc.).
  - *Requirements:* The problems for the functional interface class will be reduced through effective assignment of roles and responsibilities to humans and to automation in the performance and control of system functions; and through implementation of a dynamic function allocation strategy wherein the roles of the human and automation vary as a function of the workload imposed on the human component.
- <u>Informational interfaces</u>
  - *Components* These interfaces constitute the information needed by a human to complete a function or task, required characteristics of the information (source, accuracy, currency, quantity), and protocols and dialogues for information access, entry, update, verification,
  - *Requirements:* The objectives for effective and safe information interfaces include: the assurance that information will be available when needed, in a readily readable and understandable format, and presented at the level of specificity needed for operator decision making and action. The most effective manner in attaining these objectives is to implement the top-down HF/S process

with emphasis on the derivation of information requirements associated with specific functions and tasks, and to apply human engineering design standards in the design of information products (displays, messages, alarms, procedures, documentation, etc.)

- Environmental interfaces
    - *Components* This class of interface is concerned with:
        - the physical environment (illumination, noise, temperature, vibration, etc.),
        - workspace arrangement,
        - facility layout and arrangement,
        - environmental controls, specifically in terms of how environmental factors contribute to human performance and safety and health.
    - *Requirements:* Problems will be avoided by determining requirements for environments which are within performance, comfort and safety limits, designed in terms of task requirements with consideration for long term as well as short term exposures. Criteria also include determinations that facility designs and arrangements are based on what people must do in them; that arrangements reflect traffic patterns and cargo transfer requirements; that environmental limits comply with standards; that provisions for environmental protection have been included in the design; and that biomedical requirements and risk areas have been resolved.
- Operational interfaces
    - *Components* Operational interfaces include:
        - operating, maintenance, and emergency procedures;
        - workloads;
        - skill requirements;
        - personnel manning levels;
        - system response time constraints.
    - *Requirements:* Criteria for human workloads include concerns for the impact of workload on human error frequency, and on workload requirements.
        - Workloads will be reduced through implementation of the HF/S process described in Step 1.0. Workload will also be significantly reduced through task simplification, and provision of decision support systems.
        - Reduction in human error probability will proceed from application of human engineering standards. Investigations have demonstrated that through application of these standards, human error is reduced by from 40 to 60%.
        - The impact of human error is reduced by making systems error tolerant. This process involves determining what human errors will have serious implications for crew safety, and designing in techniques to either promptly alert the operator that an error has occurred and how to correct it; or to enable the system to continue to operate safely in the failure condition until the error is recognized and corrected.
        - The problem of absence of required skills (such as medical or dental skills) can be addressed by training crewmembers to serve as medical technicians with access to medical expertise through tele-medicine, relying on remotely located medical experts to assist in a diagnosis of procedure over a real-time, immersive telecommunications link.
- Organizational interfaces

        - *Components* These interfaces include the factors impacting the organization of system management functions, personnel jobs, and data.
        - *Requirements:*
            - Administrative workloads are reduced through enhanced office automation, and through increased crew continuity.
            - Improvement of procedures addresses the extent to which required levels of human performance can be assured given time constraints. HF/S improves the accessibility, content, and organization of procedures by ensuring that the procedure is complete, correct, clear, concise, current, consistent, and compatible with the reading/language/skill levels of the users.
            - Lines of authority will be optimized when position descriptions are based on functions allocated to the position and include duties, jobs, responsibilities, levels of authority, tasks and decisions appropriate for each position; that assignment of duties and tasks to each position is realistic; that duties and jobs are consistent with those found in existing systems; and that data required to perform functions and tasks are available, current, and identifiable.
    - <u>Cooperational interfaces</u>
        - *Components* These interfaces are primarily concerned with communication, collaboration, and team performance.
        - *Requirements:*
            - HF/S objectives in optimizing communications are directed at improving both the media and the message. Specific requirements for media design include speech intelligibility and communications device operability. HF/S concerns for the message include message standardization, use of constrained language, controlled syntax, and restricted vocabulary, methods of coding message priority, and human error potential in message transmission.
            - Concerns for collaboration and team performance center around the requirements for crew resources management with emphasis on team interaction, leadership/followership, clarity of communications, workload distribution, cooperative problem.
            - Provision of safety in-depth can be achieved through collaboration between the human and an intelligent decision support system which prompts and cues the human concerning what may be the cause for the problem, and approaches for problem resolution.
    - <u>Cognitive interfaces</u>
        - *Components* Components of the cognitive class of human interfaces include:
            - decision rules,
            - information integration,
            - problem solving,
            - instructional materials and systems,
            - short term memory aids,
            - cognitive maps,
            - situational awareness.
        - *Requirements:* Human computer interaction is enhanced, and erroneous expectancy avoided, through standardization of design. Design standards based

on human computer interface guidelines, design conventions, and human engineering standards will facilitate human interactions with automation. Perceptual and cognitive tunneling is avoided through operator's associate aiding wherein the decision support system keeps the operator aware of the full range of possibilities or implications.

- In designing to facilitate human-computer interaction the major requirement is that interfaces be usable to the human user. In this context usability of a system interface refers to extent to which:
  - human-computer interfaces have been designed in accordance with user cognitive, perceptual, and memory capabilities;
  - software command modes are transparent to the user;
  - displays are standardized and are easily read and interpreted;
  - the user is always aware of where he or she is in a program or problem (situational awareness);
  - procedures are logically consistent;
  - user documentation is clear, easily accessed, and readable;
  - on-line help is available and responsive;
  - the user is only provided with that information needed when it is needed;
  - the user understands how to navigate through a program and retrieve needed information.
- The importance of the design for usability in software development is evident in that: (a) the human computer interface comprises from 47% to 60% of the total lines of code; (b) a graphical user interface accounts for at least 29% of the software development budget; and (c) 80% of costs associated with the software life cycle (design, development, implementation, and maintenance and operation) accrue during the post-release maintenance phase of the life cycle, and furthermore, 80% of this maintenance is attributable to unmet or unforeseen user requirements. Therefore, 64% of the life cycle costs associated with a software system is due to changes required to improve the interface between user and computer.

- <u>Physical interfaces</u>
  - *Components* Physical interfaces include the physical, structural, and workstation elements with which the human interacts in performing assigned tasks. Interfaces include:
    - workstations,
    - control panels and consoles,
    - displays and display elements (screens, windows, icons, graphics),
    - controls and data input and manipulation devices (keyboards, action buttons, switches, hand controllers),
    - labels and markings,
    - structural components (doors, ladders, hand holds, etc.),
    - maintenance design features.
  - *Requirements:* The major requirement for the optimization of physical interfaces is the development of design concepts which are (1) in compliance with human engineering design guidelines and standards, and (2) demonstrated to be operable, usable, maintainable, and safe through use of mockups, models, and

simulations.

9.1.16 Provide HF/S training to system development personnel

9.2 Develop Decision Aiding Concepts to Improve Human Performance and Safety and Reduce Workload (A decision support system is an aid or tool, usually computerized, which assists the decision maker in the processes of formulating, implementing and verifying a decision. Characteristics of human expertise that surpass the capabilities of automation include the human capacity for creativity, adaptability, and the facility to incorporate experience, a broad focus, logical reasoning, and common-sense knowledge. The goal of a decision support system should be to capitalize on the strengths of the human along with the advantages of automation.)

9.2.1 Identify the functions to be performed by decision support systems

- Identify tasks from the task analysis which require decision making, problem solving, short term memory, diagnosis, or understanding of the operational situation, and analyze information requirements for these tasks
  - identify information requirements
  - identify sources of information
  - identify need for filtering/reliability check
  - identify requirements to integrate information over time
  - identify requirements to integrate information by relationships/dependencies
  - identify requirements to integrate information by priority
  - identify requirements to integrate information by elimination of redundancies
  - identify requirements to integrate information from multi-sources
- Support decision making
  - know when a decision is required
  - formulate decision issues
  - define decision rules
  - identify patterns of response from the repertoire
  - assess these response patterns
  - implement decision process
  - obtaining and assessing feedback on decision adequacy
- Support problem solving
  - recognize the existence of the problem
  - determine problem criticality
  - characterize the problem
  - identify a range of solutions
  - assess solution tradeoffs
  - identify solution implications
  - implement the solution
  - obtain and assess feedback on solution adequacy
- Support short term memory
  - for completing the task
  - needing memory aids
  - provide prompts and cues
  - anticipate operator schedule requirements
- Support diagnosis

    - determine causes
    - determine contributory conditions
    - assess symptom patterns
    - create a model of the event
    - validate the model
    - develop insights
    - expect specific outcomes
    - counteract the role of expectancy or set
- Support the understanding the operational situation
    - break set or expectancies
    - create a world model
    - understand the world model
    - validate the model
    - define requirements for current information

9.2.2 Identify Requirements by Class of decision support system

- *on-line help* existing in most modern computer programs, the help feature explains the program and addresses specific issues either in response to operator query, or relying on a more intelligent inference of where the operator needs additional orientation, explanation, and instruction.
- *memory aids*, with some degree of intelligence for anticipating operator action requirements and providing prompts and cues concerning when and how to accomplish the action.
- *planning aid* which presents alternate approaches to reaching a goal including patterns of action from past, and relevant, situations; defines the resources needed for each alternative; describes the expected performance of the system in achieving the goals with each alternative; presents the elements of the plan for each selected alternative; and formulates the final plan with schedules, resources, constraints, and expected outcomes.
- *Intelligent tutoring system* An Intelligent Tutoring System (ITS) is an advanced training technology that combines artificial intelligence, modeling, and cognitive psychology to develop expertise. An ITS provides training for novices to experts within specific knowledge domains and also can provide certification and refresher training for all levels of expertise. There are typically three elements to an ITS: a pedagogical, knowledge delivery module (the information domain) that administers the training materials; an assessment module that attempts to measure and test student knowledge at the beginning of training and as training progresses, and a student model that maintains a dynamic model of the students knowledge in relationship to the knowledge being tutored. In decision support systems ITS technology can be applied to aid directly in job performance decision making. In cooperation with the student/user the ITS provides recommendations in decision making processes to support operations.
- *Situation awareness aid* which collects data from all available sources to characterize a model of what is happening in the external world of interest to the operator, what to expect, what actions are required, what additional information is needed, what's important, and how much time is available for completing the model.
- *real-time simulation* for investigating the potential outcome of planned activities,

assessing alternate diagnoses, and rehearsing action strategies prior to implementation.

- *cooperative, collaborative decision making* wherein humans interact with other humans and with intelligent machines which serve to enhance or augment the operator's decision-making capabilities This class of models is called cooperative decision making emphasizing the importance of the cooperation between the multiple intelligent agents, both human and machine. The machine contribution to cooperative decision making typically includes what are termed advisory strategies which include advice formulated by the machine concerning what action the human should pursue and how much time is available.
- *integration of data fusion with decision support* - data fusion is the collection and representation of data from a number of sources in order to give the operator the best current view of the situation. Decision support concentrates on the evaluation of alternatives. In any decision augmentation system, these two functions are closely coupled and the data fusion system is a major source of input to the situation assessment module of the decision augmentation system. Because the development of a decision augmentation system is dependent on the development of a data fusion system, there should be an integration of these two systems early in the development process.
- *operator's associate (or pilot, commander, evaluator, or maintainer)* this class of decision support systems incorporates many of the features of categories described above to enable the intelligent machine act as an aide to the human in the performance of missions, functions and tasks.

9.2.3 Identify decision support system requirements by system element

- information acquisition and integration including identifying sources of information, filtering/reliability checking, and integrating or fusing information over time, by relationships or dependencies, by priority, by elimination of redundancies, and from multi-sources.
- intelligence - including an inference engine which enables development of a model of the human user and his or her capabilities, requirements, and expected needs for information and support; a world model defining what is happening in the real world environment and how the operational system must interact with that environment; and a information model incorporating (a) the information needed by the system throughout its operational cycle, (b) a determination of what information is currently available, and what is not, and (c) a prioritization of the information in terms of what's important for achievement of system goals. The intelligence feature of a decision support system also enables it to perform some or all required activities, to monitor and support human performance activities, and to cooperate with the human in joint conduct of activities.
- explanation facility - whereby the decision support system can inform the human as to what it "knows", why it recommends a specific course of action, and what will be the expected consequences of a course of action.
- knowledge-base - the repository of the knowledge necessary for the machine system to successfully achieve its assigned role in operational system operation.
- human-machine interface which provides the basis for the interaction between the human and the decision support system.

9.2.4 Develop the decision support system concept

- The role of the human is defined in each allocation, and requirements to support the assigned role of the human are described. A reengineering of the function allocation strategies in existing systems is also conducted wherein attempts to reduce human workload are developed through alternate approaches at function automation, function consolidation, function elimination, and function simplification.
- When automation of functions has been established, the role of decision support systems in function automation is essentially to serve as the interface between the human and the automated system. In this regard, the decision support system assists the operator in achieving the role assigned to human performance for each function by supporting situation assessment, enabling simulations, advising how much time is available, explaining its recommendations, and supporting verification of decisions.
- Decision support systems also support function consolidation by supporting cross-training across operational positions by integrating data from different sources, mission areas, and domains, and by distributing workload among remaining operators.
- Decision support systems support function elimination by generating a streamlined procedure to operations wherein in a time constrained situation selected functions and tasks are skipped.
- Decision support systems assist in function simplification by directly reducing the workload associated with a task or sequence of tasks. The decision support system reduces cognitive workload by reducing cognitive task demands. Reduction of cognitive task demands involves:
    - reducing the number of cognitive tasks
    - reducing complexity of cognitive tasks
    - reducing decision making time
    - reducing special skills and knowledge required
    - reducing levels of skills
    - reducing training
    - reducing the amount of information to be processed
    - reducing the complexity of the information processing,
    - reducing number of decisions and options to be handled
    - reducing requirements for information integration
    - reducing the complexity of decisions/actions
    - improving decision accuracy
    - improving decision timeliness
    - improving confidence in decision making
    - improving problem solving performance
    - enhancing short term memory
    - enhancing diagnosis performance
    - enhancing understanding of the operational situation
- Design to avoid erroneous expectancy is exacerbated in times of stress, leading to reduction in the cognitive focus or cognitive tunneling. The cognitive tunneling resulting from stress is defined in terms of subjective importance; performance of those tasks or processing of that information thought to be most important remains unaffected while processing information with lower perceived priority is filtered (Huey and Wickens, 1993).

- Design to avoid complacency, wherein operators of high technology, complex and sophisticated systems tend to become overly complacent, ascribing an extreme level of confidence on reliable system operation.
- Design to reduce stress - Concerning the impact of psychological stress in human error causation, it is important to note that stress in and of itself does not generally lead to the errors. Stress is involved in emergency situations but debilitating stress results from operators' not being able to know with accuracy what is happening in the real world, and how they should act in accordance with this knowledge. The inability to formulate an accurate and responsive model of the situation itself leads to stress, which results in a degraded ability to diagnose the problem due to cognitive tunneling. A major role of a decision support system in reducing human error potential should be to reduce the potential for erroneous expectancy and complacency by providing the human operator with a valid model of the world, and a clear statement of what to expect from the automated system. The decision support system will avoid cognitive tunneling by continually keeping the operator abreast of alternate explanations and possible causes.
- Design to avoid human errors through error checking. In this approach the intelligent machine, working with a model of the user, expects certain responses in certain situations. Where another response is made, the machine can query the user "did you intend to perform action X rather than action Y?" The user should be able of selecting the magnitude of this check feature by applying it to all tasks, or limiting it to high priority tasks and consequences.

9.3 Develop Maintainability Design Concepts to Improve Human Performance and Safety and Reduce Workload

9.3.1 Reduce the need for maintenance

- employ highly reliable equipment - inherent reliability is built into a system during its design phase and lack of control and direction during this period can result in costly retrofits or poor service reliability during the life cycle of the system
- rely on increased redundancy
- rely on automated test equipment - test, measurement, and diagnostic equipment (TMDE) issues include:
  - the degree to which equipment performance/status data can be sensed, processed, integrated, and diagnosed to provide recommendations to the watch-stander as to what faults have occurred, what equipment has failed, how has it failed, what is the cause of the failure, and what can be done to correct it.
  - modeling of failure modes will be an important tool in the identification of the roles of the human vs automated test equipment in the identification and diagnosis of a problem.
  - need for data standardization - with the advent of digital controls and with most of the man-machine interface inherent in a display screen, there is a need fore standardization in information display methods to enable CG personnel to operate the diverse information and control systems.
  - Task simplification will be required in specifying the usability of interfaces between the human maintainer and the TMDE.
  - The TMDE must provide decision aiding to maintenance personnel concerning

the fact that a failure is predicted, or has already occurred, diagnostics concerning what system elements are involved, the expected trend of the condition, and what the maintenance system/human can and should do.

- address human reliability to reduce the incidence and impact of human operator errors;

9.3.2 Reduce the time to repair

- HF/S issues in reducing the time to repair (MTTR) addresses human decision-making capabilities, improving maintenance access, simplifying design concepts, improving alarms and annunciators, enhancing procedures, using replaceable modules, optimizing the system's accessibility, including maintainer-centered diagnostics as part of the system, etc. The major issues are: what can be done to reduce MTTR of existing equipment; and how to design for reduced MTTR in emerging systems.
- In the modeling and simulation area maintenance task analyses will identify specific maintenance requirements such as needs for access, features of alarms and annunciators, and requirements for removal, replacement, calibration, test, and verification of components. Human-in-the-loop simulations will confirm workloads and performance problem areas, and will validate design concepts.
- Human engineering design principles, standards and design methods for human-machine interfaces used in maintenance actions. Standards in ASTM 1166 will be implemented to provide the human engineering design criteria. For example, in the area of alarms and annunciators, design standards will be required for such characteristics as:
    - alarm detectability (over a broad range of noise environments and observer characteristics)
    - masking potential of combinations of alarm signals
    - discriminability (among the alarms and among other ambient noises such as telephones and communications devices)
    - recognizability
    - stereotypic alarm associations
    - auditory localization
    - acoustic penetration/area of coverage
    - stereotypic associations with alarm importance
    - extent to which alarms invoke resident response
- Maintenance task simplification is a major contributor to reduced MTTR. Special attention in the HF/S program must be given to reducing:
    - the amount of information to be processed,
    - complexity of the information processing,
    - number of decisions,
    - complexity of actions,
    - needs for interactions with other personnel,
    - extent and complexity of communications,
    - task performance accuracies,
    - special skills and knowledge required,
    - the level of stress associated with the performance of tasks under representative mission conditions,
    - tight time constraints.

- Decision aiding is provided to support the role of the human in maintenance functions. Decision aiding supports the identification that a decision is required, and provides the information, feedback, and decision rules for making and verifying a decision.

9.3.3 Reduce the incidence and impact of maintainer human error. Maintainer error rates will be reduced through

- application of human engineering design standards,
- improved maintainer training,
- design of the system to accommodate "one-way" or "any way" spare parts,
- design with replaceable modules at the repair site,
- employment of maintainer-centered diagnostics,
- annunciated warnings when incorrect parts are installed,
- similar approaches to reduce the likelihood of error occurrence, and design of the system to be error tolerant.

9.3.4 Reduce maintainer workload and improve productivity:

- Workload is reduced, and productivity improved through the use of
  - common maintenance procedures,
  - common consoles,
  - improved identification and labeling of components,
  - improved design of human-machine interfaces,
  - improved maintenance information handling,
  - improved automated test and diagnosis,
  - maintenance job design/job aids to reduce the need for multi-person maintenance tasks.
  - Maintainer workload and productivity can be optimized through the implementation of an Intelligent Maintainer Associate (IMA) which will assist the maintainer in monitoring systems and equipment, and responding to faults and maintenance requirements. Aiding provided by the IMA will include:
    - detection of faults,
    - prediction of maintenance actions,
    - summarization of prior history of specific items of equipment,
    - isolation of faults to a system, condition, cause, and component ,
    - advice on how and when to respond.

9.3.5 Reduce maintainer skill requirements and training burden:

- Maintainer skill requirements and training burden will be reduced through design simplification, procedures improvement, application of advanced instructional technology, and use of decision aids, and by providing maintenance personnel with expert advise and decision aiding to reduce the number and scope of maintenance skills required on board.
- On-board training requirements include:
  - requirements for training of all maintainers at all workstations and duty positions
  - requirements for training devices, trainers, and part-task and full task simulators
  - training requirements must be based on job-task requirements

    - training requirements for the new system should be consistent with the requirements for similar systems
    - training requirements must be consistent with required maintainer skills and knowledge
    - training device requirements should be based on specific skills to be acquired
    - training device requirements should be based on criteria for judging/ demonstrating that requisite skills are learned
    - training device performance measures should be identified.
    - the level of fidelity required in a trainer should be specified.
    - training device requirements should include an indication of the degree to which extraneous factors must be controlled
- Maintenance skill requirements are also reduced by providing maintenance personnel with expert advise and decision aiding in one or both of two approaches: by means of on-board intelligent maintainer associate systems or expert systems to support maintainer decision processes, and by means of tele-maintenance wherein maintenance advice is provided to the on-board maintainer via communications links with human or automated expertise at a remote location.

9.3.6 Improve the design for maintenance access

- According to ASTM F 1166-95, proper accessibility is a fundamental requirement of good maintainability and must be designed into the equipment and overall system. Accessibility means that all maintenance activities will performed in a workspace where human-machine interfaces are easily and safely reachable and readable.
- The major issues in maintenance access revolve around the extent to which the maintainer is provided with sufficient clearance to safely and effectively: maneuver into a workspace; see and inspect items of interest including hazards; reach and manipulate structural components; and remove, replace, handle, and transfer equipment units of a wide variety of sizes and weights.
- To ensure maintenance access, a maintenance workspace must be designed for:
    - ease of repair in place;
    - ease of removal-replacement;
    - ease of calibration and adjustment;
    - ease of inspection and monitoring;
    - access to service and replenishment points;
    - access to spaces;
    - location of alignment aids for insertion, installation, and replacement;
    - location of precautions, warnings and special instructions.
- Maintenance access requirements will place primary importance on the result of equipment installations, since the actual accessibility for maintenance will depend on equipment location, orientation, and spatial relationships with other equipment, arrangements, piping, cable runs, etc.
- Installation drawings must be reviewed to identify potential access problems.
- Lessons learned from baseline comparison systems should also be collected to identify problems for access with existing systems.
- Mockup and/or model walkthroughs should be used to identify design problems and operational difficulties. The mockups should be full scale representations of the essential attributes of an installation design approach, constructed from foam-cor or

plywood for ease of construction and modification. Models are scaled down representations of larger areas depicting the installation concepts in existing arrangements.

- The HF/S concepts to be developed will address the major user-machine and user-facility interface issues. HF/S concepts will either be developed or will reflect an assessment of architectural and engineering design concepts from a HF/S point of view. Specific HF/S concerns with concepts will include the following:
    - Compartmentalization concepts - room occupancy and utilization
    - Arrangements concepts - traffic patterns
    - Accommodations concepts - compartment equipment and fixtures
    - Safety concepts - concepts for hazard avoidance, guarding, or warning
    - Facility maintenance concepts - workspace and access space required
    - Equipment maintenance concepts - maintenance access
    - Environmental control concepts
    - Communications concepts
    - Supply/support concepts
- In the determination of access requirements, architectural and engineering constraints will be identified which include situations where the design of the user-machine and user-facility interfaces is constrained by structural, engineering or cost factors and where the HF/S effort will have to comply with the constraints.

9.3.7 Improve accessibility, usability and readability of maintenance procedures

- Procedures and technical documentation will be formatted, annotated and displayed by hardcopy, by call-up on a PC, or by an intelligent maintainer associate (IMA). Given the implementation of the IMA, hard copy procedures and technical documentation will not be required.
- Procedures and technical documentation design requirements include requirements for additional information associated with each maintenance task; requirements for information integration; and information presentation design requirements for information format, information source, information quantity, information currency, information update rate, and relationship to primary display
- Procedures/documentation design concepts include
    - information presentation concepts (dedicated, space shared, or time shared;
    - overlay;
    - video - pictorial including video, graphics, animation, and stills); information integration concepts (integration of information from varied sources, including communications);
    - information update concepts,
    - information application concepts.

9.3.8 Enhance system affordability - life cycle costs will be decreased by reducing:

- costly errors and accidents;
- system downtime and time to repair;
- training time through task simplification and use of on-line decision aiding,
- numbers and skills of maintenance personnel required.

9.4 Develop HF/S Information Management Concepts to Improve Human Performance and Safety and Reduce Workload

9.4.1 Define the role of the human in a complex information management process.

- optimize the role of the human in a complex system, using human capabilities more effectively while compensating for human limitations, and integrating the human and the machine to establish a synergistic system.
- determine the role of the human vs automation in the performance of each function or task. The emphasis on the role of human in the system acknowledges the fact that the human has some role in every system function or task. In some cases that role may encompass actual performance of the function or task.
- determine how an assigned role for human performance may change with changes in operational conditions. Thus a task optimally performed by a human under certain conditions of workload, time constraints, or task priority, may be more optimally automated under other conditions.
- define the roles of humans in automated functions or tasks, such as that of a manager, monitor, decision maker, system integrator, or backup performer.

9.4.2 Identify, develop, and integrate information management technologies that will reduce human error and operator cognitive workload while enhancing the decision making capabilities of CG personnel.

- integrate information and provide information products to users so as to minimize the probability of human error. The leading cause of human error is unavailability and/or inadequacy of needed information in an environment of information overflow.
- The need for information integration is related to the broader need for an integration of human performance concerns into the design of CG systems.
- develop systems which are more effective, efficient, affordable, supportable, survivable, operable, and usable.

9.4.3 Standardize information products such as displays, communications, and documentation.

- improve and standardize operational displays based on measurable improvements in human performance.
- lack of display standardization, and the resulting multiplicity of displays, place a heavy workload on the individuals who need a coherent picture of the operational situation based on differing and possibly conflicting operational representations. This increased workload can lead to degraded human performance and an increased probability for human error, especially under conditions of increased stress.
- lack of symbology standardization also impacts training requirements in that different training programs are needed for the different display systems.

9.4.4 With the diversity of information sources, a critical need exists in the CG for more effective techniques to ensure information transfer timeliness, responsiveness, and appropriate granularity. Information transfer encompasses information communication and information dissemination. To be useful, needed information must be conveyed to the intended user so as to be available when required and at the level of specificity required.

9.4.5 With the quick responsive capability requirement imposed on today's mission systems, a need exists for system recompilation, which extends to the adaptation and tailoring of system information to meet the unique requirements of the mission with a maximum of operational effectiveness and system flexibility, supportability and manageability. The capability of a system to recompile, to adapt and adjust information processing and information products to the unique requirements of a mission is critical.

9.4.6 Improve the skills and training of personnel in the processing and handling of information.

- design issues associated with personnel skills and training requirements for information management activities include:
  - determination of special skills, including cognitive skills,
  - identification of initial training and refresher training requirements,
  - development of training systems requirements.
- define concepts for knowledge and skill training of information processing system personnel, on an individual and team basis, both in the schools as well as on-board. On-board training should also encompass the use of on-board decision aids to integrate available information and assess alternate courses of action.

9.4.7 Provide the capability to prioritize information in real time.

- with modern information presentation techniques, much pertinent available information can be conveyed in windows or multi-function displays.
- prioritize the information to ensure that the user has ready access to the category of information needed for the mission or operation.

9.4.8 Provide quantitative measures of effectiveness to assess the adequacy of information management activities, techniques and systems. These measures will support decisions that the information management process is effective, or that it needs improvement.

9.5 Develop facility/arrangements concepts

9.5.1 Identify Facility Design Issues

- Workspace-facility design requirements
  - workspace dimensions- safety requirements
  - equipment arrangement requirements
  - compartment arrangement requirements
  - space configuration requirements
    - free volume
    - traffic patterns
    - manning levels

      - layout arrangement
      - use frequency/duration
      - growth potential
      - relationship to other spaces
    - material requirements
      - furnishings
      - equipment operability
      - equipment maintainability
      - equipment safety
      - decor
    - environmental requirements
      - expected levels
      - environmental controls
    - HF/S facility requirements inputs to Data Sheet F of the LSAR.

9.5.2 Develop Workspace and Facility Design Requirements

    - review task analyses to identify where tasks must be performed
    - allocate tasks and task performance requirements to facilities

9.5.3 Identify facility user functions and associated facility requirements

- enter facility
  - access location requirements
  - access identification requirements
  - access dimension requirements
  - access safety requirements
- prepare the facility
  - control of lighting requirements
  - control of temperature and humidity
  - control of ventilation
- configure the facility
  - free volume requirements
  - arrangement of locomotion spaces
  - arrangement of cargo transfer spaces
  - arrangement of work space
- inhabit the facility
  - lighting requirements and constraints
  - noise constraints
  - vibration constraints
  - temperature/humidity requirements and constraints
  - ventilation requirements and constraints
  - radiation constraints
  - human needs
- access workspace
  - access standardization requirements
  - access illumination
  - access safety

- access procedures, documentation, equipment
    - access storage requirements
- access consoles and panels
    - console-panel arrangements requirements
- perform facility operations
    - furnishing requirements
    - support equipment requirements
    - storage space requirements
    - workspace requirements
    - environmental factors
- perform tests within facilities
    - test point location and arrangement
    - access and operation of test equipment
    - communications requirements
    - visual access of test personnel
    - automatic test equipment requirements
- perform facility maintenance-arrangement of equipment and components
    - location and access of tools
    - component identification
    - methods of indicating maintenance in programs, e.g., tag out
    - component handling, moving, lifting equipment
    - component design for repair in place
    - component location for maintenance access
    - component design for ease of removal-replacement
    - component design for ease of calibration, adjustment
    - component design for ease of inspection, monitoring
    - location and arrangement of service points, replenishment accesses
    - location and access to spaces
    - design and location of alignment aids for insertion, installation, replacement
    - design and location of precautions, warnings and special instructions
- perform locomotion in facility
    - traffic pattern requirements
    - route characteristics and dimensions
    - manning requirements
- perform cargo transfer within facility
    - cargo handling and transfer requirements
    - control requirements
    - material handling equipment requirements
- respond to alarms
    - signal coding requirements
    - signal intensity
    - location and arrangement of signals
- communicate within facility
    - visual access requirements
    - speech communication requirements
    - noise levels
    - communications media requirements
- communicate with personnel exterior to the facility

        - communications equipment location and access
        - speech intelligibility limits
        - noise levels
    - use emergency equipment in the facility
        - standardization of fire fighting equipment
        - protective clothing storage
        - special instructions for emergency equipment operations
        - breathing apparatus requirements
        - body protective clothing requirements
        - compatibility of protective clothing with operations
    - facility emergency egress
        - location of egress
        - egress illumination

9.5.4 Review facility design concepts in predecessor/baseline systems

9.5.5 Review facility design problems from field feedback

9.5.6 Conduct walkthrough of task sequences

- using predecessor facility
- using facility mock-ups
- using scaled down models
- using computer simulations
- using CAD

9.5.7 Develop alternative facility concepts

9.5.8 Integrate facility concept selection for different task sequences

9.5.9 Conduct analyses to develop facility design criteria

9.6 Develop procedures/documentation concepts

9.6.1 Develop Procedures/Documentation requirements

- review operability design concepts
- identify requirements for additional information associated with each operational/ maintenance task
- identify approaches for support information in predecessor and baseline systems
- identify information presentation design requirements
    - information format
    - information source
    - information quantity requirements
    - information currency requirements
    - information update rate
    - relationship to primary display

9.6.2 Conduct Analyses to Develop Procedures/Documentation Concepts

- identify information presentation concepts
  - hard copy
  - hand held-other than text (e.g. special calculators, lookup tables, graphics)
  - displays (dedicated or shared; space shared or time shared; overlay; video-pictorial; fiche; pictures; text)
- Conduct studies and simulations to develop alternative concepts and to evaluate competing procedures and documentation information presentation concepts
- conduct tradeoffs of alternate concepts
  - develop tradeoff criteria from requirements
  - develop tradeoff criteria from predecessor system performance, availability, readability and cost
  - conduct tradeoffs

9.6.3 Conduct Analyses to Develop Documentation Design Criteria

- integrate selected concepts over missions, conditions and sequences
- develop design criteria for selected concepts

9.7 Develop HF/S Inputs to NDI Concepts

9.7.1 Develop and apply procedures and processes for applying HF/S in the selection of NDI.

- Identify HF/S Inputs to NDI Concepts and Issues
  - Determine the extent to which the NDI must meet users' needs and function in users' environment.
- Determine HF/S issues in NDI flexibility in operational requirements.
- Provide inputs to ensure that the developer is responsive to legitimate needs but be conscious of technical risks and affordability constraints.
- Provide inputs to ensure that the user is realistic in stating needs and considering trade-offs. After weighing the benefits of proven capability and more rapid deployment against any performance limitations, the user must determine whether the trade-offs are acceptable. When performance trade-offs are made, they must be formally changed in operational requirements documents.
- Tailor the acquisition process for NDI
- Provide inputs to Effectiveness Trade-offs.
  - Assess NDI reliability vis-a-vis the total system reliability.
  - Provide inputs to evaluate producers' processes, production methods, and production control procedures.
- Provide HF/S inputs to the determination of Life Cycle Cost.
  - Determine how to identify which NDI approach has the lowest projected life-cycle cost, within acceptable risks, and meets essential requirements, including human performance and safety requirements.
  - Determine how to identify which NDI approach has the lowest manning requirements including operations and maintenance.
  - Determine how to identify which NDI approach has the most effective training

    program
    - Determine how to identify which NDI approach has the least safety and health hazards
    - Determine how to identify which NDI approach has the best mean time to repair
    - Determine how to identify which NDI approach has the best overall availability
    - Determine how to identify which NDI approach has the best overall supportability
- Provide HF/S inputs to the determination of ILS requirements
- Identify Safety and Environment Issues.
    - Determine the extent to which NDIs must comply with CG standards.
    - Determine how to identify hazards
- Determine workload and Personnel Issues.
    - Determine how to identify manning requirements
    - Determine how to identify skill requirements
    - Determine how to identify workload requirements
- Determine Training Issues.
    - Determine how to identify training requirements
    - The acquisition of NDI may affect both formal classroom and on-the-job training.
    - Determine how to identify training device requirements
    - Training plans should consider not only the impact on training but also the possibility that the item may require new, additional, or modified training devices.
- Determine Human Performance Issues
    - Human error potential
    - Time to respond
    - Time to perform
    - Workloads
    - Determine HF/S Test and Evaluation Issues
        - HF/S T&E requirements
        - HF/S T&E methods, measures, criteria and procedures
    - Determine HF/S issues for NDI Modification.
        - Determine what modifications are required to the man-machine interfaces, operating environments, maintenance access provisions, maintenance workspace, manning levels, skill requirements, training, and safety provisions.
        - Determine HF/S inputs to evaluation of the total effect of modifications, particularly in the area of logistics support.
- Identify HF/S Inputs to market surveys
    - Provide HF/S Inputs to Market Surveillance
        - Review technology requirements
        - Identify technology available
        - Assess technologies
    - Provide HF/S Inputs to Market Investigation Plan
        - Finalize the operational requirement;
        - Develop a form, fit and function description to obtain competition;
        - Determine logistic support requirements;
        - Determine what additional testing is required.
    - Provide HF/S Inputs to Market Investigations.
        - System Performance Requirements (detailed operating parameters for hardware and software, environmental conditions, usage, system interface,

        integration requirements, required software, language, speed, throughput, ports, memory and expansion potential, human operator performance requirements
        - Reliability, Maintainability, and Survivability (human reliability requirements - error rates, human Maintainability requirements
        - Logistics Support, maintainer proficiency levels, maintenance environment, supply support, support equipment needs, training needs, technical data needs
- Input to Market Investigation Questions to suppliers.
    - what portions of the system or equipment do you intend to provide in the form of NDI equipment?
    - how, in detail, will each item or assembly meet stated requirements?
    - must any of it be modified to meet requirements?
    - how stable is the design of the equipment?
    - how long has the item been on the commercial market?
    - How many are currently in commercial use?
    - What are the prospects for product longevity?
    - How long will you support it?
    - what is the reliability history of the product (e.g. mean time between failure, corrective maintenance actions, etc.)?
    - what are human error modes associated with use of the item?
    - what are error rates? Impacts? Correction provisions?
    - what are the maintainability features of the design?
    - what support is provided the maintainer?
    - what is the Mean time to repair?
    - what flexibility do you offer for government maintenance?
    - if the NDI is to be used as part of a system, how do you perceive the criticality of interfacing with other subsystems, software, etc. for overall system integrity?
    - can the proposed item(s) be maintained according to the conditions we have given you, or will special arrangements be required? What are they?
    - what is your estimate of your product's life cycle cost over a X year(s) period?
    - what training is needed to operate and maintain your product, and is such training available from any source?
- Analyze data from market investigations
    - product quality, electromagnetic compatibility, reliability, human performance, training, and maintainability experience of similar users.
    - Are modifications to the NDI needed?
    - Stability of current configuration and technology.
    - Packaging, handling, storage, and transportation practices.
    - Commercial market acceptability-related data
    - Need for any pre-production or production qualification testing and special quality assurance requirements.
    - Hardware, software, and workload interface issues such as human factors and product safety as experienced by similar users.
    - Repair parts availability and lead times, documentation, pricing, and distribution systems.
    - Customer service, installation, checkout, and user maintenance instructions.
    - Requirements and provisions for workload and personnel.

    - Competitive or sole source repair and support base.
    - Training and training support requirements.
    - Requirements for and availability of tools, test equipment, computer support resources, calibration procedures, operations, and maintenance manuals.
    - Warranty procedures and commercial repair capabilities.
    - Degree of technical data package availability/adequacy.
  - Identify human performance requirements for NDI
    - determine human error potential in NDI operation
      - likelihood of error occurrence
      - likelihood of error detection
      - likelihood of error correction
      - impact of errors on performance and safety
      - data on error rates and effects
      - identify the extent to which the error potential can be reduced through design modifications
    - determine human error potential in NDI maintenance
      - likelihood of error occurrence
      - likelihood of error detection
      - likelihood of error correction
      - impact of errors on performance and safety
      - data on error rates and effects
      - identify the extent to which the error potential can be reduced through design modifications
    - Determine potential problems with time to respond/perform
      - Determine potential problems with reaction time
      - Determine potential problems with time to perform
      - Identify the extent to which the timing problems can be alleviated through design modifications
    - Determine the extent to which NDI tasks are unduly complex - determine the potential for task simplification to reduce workload/manning.
      - identify the potential for reducing physical task demands
      - identify the potential for reducing cognitive task demands
      - identify the potential for reducing perceptual-motor task demands
        - Reduce the amount of information to be processed,
        - Reduce the complexity of the information processing,
        - Reduce the number of decisions and options to be handled,
        - Reduce the complexity of actions,
        - Reduce the needs for interactions with other operators,
        - Reduce the extent and complexity of communications,
        - Reduce the task performance accuracies required,
        - Reduce the special skills and knowledge required,
        - Reduce the levels of skills such as reading comprehension,
        - Reduce the level of stress associated with the performance of tasks under representative mission conditions,
        - Reduce the time constraints.
      - Identify how task simplification will modify task sequences and/or reduce the likelihood of human error
    - Establish criteria which address the adequacy of the system design for

operability
    - adequacy of communications
    - workloads associated with operations
    - projected error occurrence rates
    - expected effects of errors
    - projected error recovery rates
    - expected information handling performance
    - man-machine interface design compliance with standards
    - adequacy of the design for operability
  - Establish criteria which address the adequacy of the system design for maintainability
    - expected fault detection performance
    - expected fault isolation - troubleshooting performance
    - expected accessibility design
    - adequacy of the design for maintainability
- Identify HF/S supportability requirements for NDI
  - Identify procedures/documentation requirements
  - Evaluate procedures/documentation
  - Identify impacts of HF/S on life cycle costs
    - Determine which NDI approach has the lowest projected life-cycle cost, within acceptable risks, and meets essential requirements, including human performance and safety requirements.
    - Determine which NDI approach has the lowest manning requirements including operations and maintenance.
    - Determine which NDI approach has the most effective training program
    - Determine which NDI approach has the least safety and health hazards
    - Determine which NDI approach has the best mean time to repair
    - Determine which NDI approach has the best overall availability
    - Determine NDI approach has the best overall supportability
    - Determine NDI approach has the least overall risk
    - Determine NDI approach has the best overall affordability
- Identify safety and health requirements for NDI
  - Determine hazards due to materials
  - Determine hazards due to sharp edges/corners
  - Determine hazards due to lasers
  - Determine hazards due to RF
  - Determine hazards due to breakage
  - Determine hazards due to explosion
  - Determine hazards due to electric shock
  - Determine hazards due to environmental factors
  - Determine hazards due to man-machine interface design
- Identify workload & personnel requirements for NDI
  - Identify workload requirements from system acquisition documentation
  - Identify workload requirements from ILS/LSAR documentation
  - Identify workload requirements from lessons learned
    - problems in existing systems (excessive workloads, unbalanced or highly variable workloads, understaffing problems, overstaffing problems, unavailability of personnel with requisite skills

        - workload distribution in existing systems
        - functional allocation to human and automated performance in existing systems
        - constraints on personnel availability
        - results of attempt to reduce system manning
            - Identify workload requirements from HF/S issues
            - Identify workload requirements from function/task analysis data
            - Identify workload requirements from manning/workload studies
    - Identify requirements for manning
        - investigate alternate workload/skill reduction options, such as cross training, automation of manual operations, improved design, changes in policy and doctrine
            - identify task sequences where workload/skill reduction is feasible and potentially beneficial
            - conduct workload analyses of alternate workload reduction approaches
- Identify training requirements for NDI
    - Identify training requirements from system acquisition documentation
    - Identify training requirements from lessons learned
        - training problems in commercial systems
        - training effectiveness in commercial systems
        - training devices and equipment used in commercial systems
        - applications of embedded training technology
        - applications of onboard training technology
        - requirements for special skills
    - Identify training requirements from HF/S issues
    - Identify training requirements from function/task analysis data
    - Integrate training requirements
        - identify skill requirements by tasks
        - integrate manning and skill requirements across task sequences
        - identify training system requirements in terms of
            - training objectives
            - training method requirements by training objectives
            - training measurements requirements by training objectives
            - training material requirements by training objectives
            - training media requirements by training objectives
            - training management requirements
    - identify training device design requirements
        - training objectives addressed
        - information reception media
        - skills acquisition media
        - fidelity levels
        - display formats
        - range of conditions
        - use of augmented feedback
        - use of prompting and cueing
        - programming
        - use of CAI/CMI

            - degree of flexibility to different system configurations
            - instructor interfaces
            - data acquisition and recording requirements
            - embedded training requirements
                - review training devices approaches implemented in predecessor/ baseline systems
                - identify problems with existing training devices for selected training objectives
    - Identify survivability requirements for NDI
        - Assess availability/adequacy of protection systems and devices
        - Assess expected human performance wearing protective ensembles
        - Assess adequacy of countermeasures
        - Assess adequacy of the design for survivability
    - Identify test and evaluation requirements for NDI
        - Identify extent to which T&E data will influence selection of design concepts, and incorporate into T&E planning
        - Identify the extent to which HF/S T&E will be accomplished under operationally realistic conditions using personnel deemed to be typical users
        - Identify extent to which results of evaluations of predecessor systems will input HF/S T&E exercises
        - Identify NDI test and Evaluation issues
            - Identify HF/S inputs to T&E
            - Identify categories of HF/S T&E required
            - Identify overall T&E objectives
            - Identify overall objectives of HF/S T&E
            - Integrate HF/S T&E objectives with system-level T&E objectives
        - Plan and conduct HF/S T&E
    - Develop NDI Procurement Requirements
    - Identify ILS requirements for NDI
        - criteria which address the adequacy of the system design for supportability
        - determine the adequacy of system documentation
        - determine the adequacy of spares access
        - determine the adequacy of the design for supportability

9.7.2 Provide HF/S input to the Commercial Item Description

- Establish requirements for the Commercial Item Description (CID) - a simplified specification that describes, by salient functional or performance characteristics, the available, acceptable commercial or commercial-type products that will satisfy the Government's needs. It is a type of Federal specification to prepare technical documents that are easier for suppliers to use and that allow manufacturers to provide products from their standard production line.
- Prepare the CID Abstract - a statement that combines the scope and intended use of the item to provide potential suppliers and users a brief description of the item(s), which will allow suppliers to decide if they may be able to supply the item and users to decide if the CID is appropriate for use in meeting their requirements. The abstract may also be used in the synopsis of the procurement in the Commerce Business Daily.

- Identify Salient Characteristics:
  - Describe salient characteristics which capture technical aspects of the item and provide a basis for its acceptance or rejection. User requirements and research and analysis of comparable items available commercially provide the basis for preparing the salient characteristics section of a commercial item description.
  - Referencing Military specifications and standards in CIDs is discouraged. Referencing non-government test methods and standards is the preferred method for incorporating technical characteristics, materials, and testing procedures. Commonly used commercial test methods and units of measurement should be used. If a non-government standard is not available for the entire item or sufficiently definitive, consider using non-government standards in part or as a basis. Determining the appropriate salient characteristics is an item specific, technically demanding task which is based on the judgment of the technical expert or engineer. However, user input and feedback, market research, and industry comments are essential considerations.
  - The following tools and techniques are available to the person preparing the specification in developing salient characteristics initially and in keeping them current, in response to changing user requirements and technology.
    - Test and evaluation of product samples.
    - Industry publications such as catalogs and product data sheets.
    - Technical journals.
    - Previous Government contract performance.
    - Discussions with manufacturers and users.
    - Industry references
    - Trade shows
    - Standardization organizations
- Identify Quality assurance provisions:
  - Manufacturer's Standard Quality Assurance Program - The quality assurance of products described using a CID should rely entirely or primarily on the manufacturer's standard quality assurance program in providing products for the commercial market.
  - Quality assurance provisions should be directed toward determining compliance with the salient characteristics of the CID and Government acceptance of the product.
  - Market Acceptability - Quality assurance provisions in a CID may be stated in terms of market acceptability. Market acceptability must be based on a reasonable assessment of the Government's minimum needs and should be developed considering the specific product and its market. Flexibility is encouraged in constructing market acceptability requirements to fit the product and may vary, i.e. volume of product, time on the market, etc.

9.8 Develop Human Performance Concepts

9.8.1 Identify human performance requirements from system acquisition documentation

9.8.2 Identify human performance requirements from lessons learned

- Human performance problems in existing systems

- Individual operator performance data
    - requirements in existing systems
    - concepts for enhancing and aiding human performance in existing systems
    - concepts for measuring/monitoring human performance in existing systems
    - required levels of probability of successful performance in the new system
- Team performance data
    - problems in existing systems
    - requirements in existing systems
    - concepts for interactive performance in existing systems
    - communications concepts in existing systems
    - information flow concepts in existing systems
    - cross training approaches in existing systems
- Human reliability data
    - concepts implemented in existing systems for:
        - reducing error occurrence
        - detecting error occurrence
        - correcting for errors
    - requirements in the new system for
        - minimum error occurrence rates
        - maximizing the likelihood of error detection/correction
- Human productivity
    - concepts in existing systems to increase or enhance productivity
    - constraints on productivity in the new system.
- Maintenance data
    - maintenance concepts implemented in existing systems
    - maintainability design concepts implemented
    - maintainer performance data: time and errors in fault detection, isolation, correction, and verification
    - automated diagnosis concepts implemented in existing systems
    - maintenance data base management system concepts implemented in existing systems
    - decision aid concepts implemented in existing systems
    - minimum acceptable maintainer error rates
    - human performance constraints as applied to maintenance functions
- Technical documentation data
    - document structure
    - layout concepts implemented in existing systems
    - document indexing concepts
    - document enhanced readability concepts
- concepts using electronically generated documentation

9.8.3 Identify human performance requirements from HF/S issues

9.8.4 Identify human performance requirements from function/task analysis data

9.8.5 Integrate human performance requirements

9.8.6 Develop operability design concepts

- concepts for man-machine interfaces at the system/subsystem level rather than at the individual component level
- display concepts
    - display integration concepts
    - feedback concepts
    - display mode concepts
    - large screen- group display concepts
    - computer display concepts
    - special display concepts
    - information integration levels
- control concepts
    - role-of-man in the control system concepts
    - special control design concepts
- human-computer interface (HCI) concepts
    - input/output concepts
    - data access-retrieval dialogue concepts
    - man-computer interaction concepts
    - command mode concepts
    - data base management concepts
- equipment arrangement concepts
    - workspace layout concepts
    - control-display integration concepts
    - control console integration concepts

9.9 Develop Safety/Health Concepts

9.9.1 Identify safety/health requirements from system acquisition documentation

9.9.2 Identify safety/health requirements from lessons learned

- Life support data
    - protection system concepts implemented in existing systems
        - collective protection systems
        - individual protection systems
    - damage control concepts implemented in existing systems
        - fire fighting operations
        - rescue operations
    - habitability concepts implemented in existing systems
        - environmental control
        - workspace free volume
        - support of living activities
    - design for safety concepts implemented in existing systems
        - hazard reduction/elimination
        - warnings
        - safety procedures
        - safety training
    - medical support concepts in existing systems
        - onboard services

- medical evacuation services

9.9.3 Identify safety/health requirements from HF/S issues

9.9.4 Identify workload related safety concerns

- Fatigue due to job factors
  - working hours - duration of the workday
  - watch rotation - work/rest cycles
- Fatigue due to task overloading
- Emergency response
  - all hands emergency - fire, explosion, collision, grounding
  - safety procedures
  - continue to operate safely in situations of power loss or failure of vital equipment, i.e. steering gear, navigation equipment, mooring equipment, propulsion, and cargo gear

9.9.5 Techniques to reduced workload safely

- minimize operational conditions which produce fatigue, such as,
  - exposure to environmental extremes,
  - rotating shifts,
  - extended work periods without adequate rest:
- minimize psychological stress;
- minimize equipment-design factors likely to increase the probability of errors, such as,
  - poor control and display design,
  - inappropriate allocation of command and control functions among crew members and/or among automated systems;
- maximize the opportunity for recovery from errors and incidents without damage to the crew or CG resource, e.g.,
  - sufficient crew coverage to manage worst case emergencies during critical operations,
  - sufficient information flow to maintain crew "situational awareness" under automated operation, expand the use of error tolerant equipment and systems wherein incidence of an error is readily detectable before adverse consequences, or the system can continue to operate after an error has occurred, until such time that the error can be corrected.

9.10 Develop Workload and Staffing Concepts

9.10.1 Identify workload and Staffing Requirements

- Identify workload requirements from system acquisition documentation
- Identify workload requirements from ILS/LSAR documentation
- Identify workload requirements from lessons learned

9.10.2 Develop workload/Staffing Concepts

- Identify the workload impact of the new system as compared to the predecessor
- Identify the sources of the workload resources for the new system
- Identify the new occupational specialties - requirements for high quality personnel or hard to fill occupations, and how these personnel requirements will be met
- Develop manning estimates by missions/conditions
- Develop role of human vs machine concepts
- Develop concepts for the role of man in automated activities

9.11 Develop Training Requirements and Concepts

9.11.1 Identify Skill and Training Requirements

- Identify training requirements from system acquisition documentation
- Identify training requirements from lessons learned
    - training problems in existing systems
    - training effectiveness in existing systems
    - training devices and equipment used in existing systems
    - applications of embedded training technology
    - applications of onboard training technology
    - requirements for special skills
- Identify training requirements from HF/S issues
- Identify training requirements from function/task analysis data
- Integrate training requirements
- identify skill requirements by tasks
    - job performance knowledges
    - job performance skills
- integrate manning and skill requirements across task sequences
- identify training system requirements in terms of
    - training objectives
    - training method requirements by training objectives
    - training measurements requirements by training objectives
    - training material requirements by training objectives
    - training media requirements by training objectives
    - training management requirements
- identify training device design requirements
    - training objectives addressed
    - information reception media
    - skills acquisition media
    - fidelity levels
    - display formats
    - range of conditions
    - use of augmented feedback
    - use of prompting and cueing
    - use of branching
    - programming
    - use of CAI/CMI
    - degree of flexibility to different system configurations
    - instructor interfaces

    - data acquisition and recording requirements
    - embedded training requirements
  - review training devices approaches implemented in predecessor/baseline systems
  - identify problems with existing training devices for selected training objectives

9.11.2 Develop training concepts

- Identify training requirements and estimate the effectiveness level required of the new training system
- Identify requirements for new or additional training resources
- Identify critical points in the training schedule
- Identify the impact that the fielding of the new system will have on unit readiness
- Identify whether the training base is adequate to meet surge and mobilization requirements
- Develop skill estimates
- Develop skill reduction concepts
- Develop training methods concepts
- Develop training media concepts
- Develop training materials concepts
- Develop training measurement concepts
- Develop training management concepts

9.12 Integrate Design and Readiness Concepts

9.12.1 Resolve incompatibilities

- Conduct the HF/S comparability analysis
- Identify incompatibilities/inconsistencies
- Resolve incompatibilities/inconsistencies

9.12.2 Provide concept rationale

- Summarize HF/S design concepts
- Provide the basis for design decisions underlying the concepts
- Identify concept strengths and weaknesses

9.12.3 Identify design impacts

- Describe the system concept and HF/S design concept being assessed
- Describe operator/crew tasks with the concept
- Describe high driver requirements associated with tasks and task sequences

9.12.4 Identify supportability impacts

- Describe the system concept and manning/role of man concept being assessed
- Develop a sequence of tasks to describe activities performed with the concept
- Conduct Workload Analyses
  - Determine workload levels for each position under each condition of readiness

    and selected operational scenarios
    - Identify workload overload and underload problems
    - Redistribute workloads
    - Conduct workload, manning and performance simulations
- Identify the implications of each system concept and manning/role of man concept
- Identify and describe feasible manning/workload reduction concepts
- Identify impacts of design concepts on training

9.12.5 Describe workstation concepts

- Review Man- Machine Interface Requirements - each workstation
- Integrate workstation concepts and Man-Machine Interface Design Concepts
- Integrate Man -Machine Interface Design Criteria
    - integrate selected approaches over all sequences
    - review design criteria for selected concepts
- Integrate procedures/documentation concepts by workstation

9.12.6 Describe UCI concept

- Review User-Computer Interface (UCI) design requirements
- Conduct analyses to integrate User-Computer Interface concepts
- Conduct analyses to integrate User-Computer Interface design criteria

9.12.7 Describe arrangement/facility concepts

- Review facility design issues
- Review workspace arrangements and facility design requirements
- Review alternative facility concepts
- Integrate facility/arrangements concept for different task sequences
- Conduct analyses to integrate facility design criteria

9.12.8 Describe communications concepts

- Review communications requirements
    - message requirements
    - message frequency requirements
    - communication media requirements
- Integrate communications concepts
- Integrate communications criteria

9.12.9 Describe maintainability concepts

- Review maintainability design requirements
- Conduct analyses to integrate maintainability design concepts
- Conduct analyses to support integration of maintainability design criteria

9.12.10 Describe manning concept

- Integrate manning concepts over scenarios and missions
- Integrate operations and maintenance manning concepts
- Integrate crew utilization concepts

9.12.11 Describe role of man concepts

- Review role of man concepts over different missions and scenarios
- Review workload data
- Conduct system level workload assessments

9.12.12 Describe training concepts

- Review task complexity and skill estimates
- Review training concepts
- Integrate training concepts

9.12.13 Describe training device concepts

- Conduct analyses to integrate training device requirements
- Describe training device concepts
  - type of media (information reception, knowledge based, skill acquisition, performance based)
  - type of implementation
    - part task
    - stand alone
    - full task
    - stand alone
    - embedded
  - application
    - generic to a class of systems
    - system specific
  - training approach
    - individualized-self-paced
    - demonstration
    - instructor interaction
    - computer interaction
- conduct tradeoffs of alternative concepts
  - integrate selected concepts across training objectives
  - develop training device design criteria